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## ABSTRACT

CEPUP in the Schools is a project of the Chemical Education for Public Understanding Program (CEPUP) at the Lawrence Hall of Science, University of California-Berkeley. CEPUP is a diverse educational program highlighting chemicals and their uses in the context of societal issues, so that learners experience the reality of science. This booklet gives an overview of the available modules developed for this program. CEPUP in the Schools materials are directed toward students in middle/junior high and high schools. The modules contain equipment and supplies produced by Lab-Aids and printed matter published by Addison-Wesley. An activity overview and conceptual overview are given for the following modules: (1) "Chemical Survey & Solutions and Pollution"; (2) "Risk Comparison"; (3) "Determining Threshold Limits"; (4) "Investigating Groundwater: The Fruitvale Story"; (5) "Toxic Waste: A Teaching Simulation"; (6) "Plastics in Our Lives"; and (7) "Investigating Chemical Processes: Your Island Factory." The conceptual overview includes the chemistry concepts, processes, and societal issues covered in that particular module. The activity overview describes the activities that are part of the module. Ordering information and the prices for each module are provided. (KR)

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# Issue-Oriented Science Using CEPUP

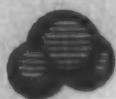


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## INTRODUCTION



The CEPUP logo represents a water molecule. Water is necessary for all life and is involved in many of our concerns about chemicals and the environment.

For further information about CEPUP, contact:

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## CEPUP in the Schools

CEPUP in the Schools is a project of the Chemical Education for Public Understanding Program (CEPUP) at the Lawrence Hall of Science, University of California-Berkeley. The project is supported by a 3-year materials development grant from the National Science Foundation and by contributions from private industry and foundations. CEPUP in the Schools materials are directed towards students in middle/junior high and high schools. Responsibility for the content, approach, and testing of materials is with the CEPUP staff at the Lawrence Hall of Science, University of California at Berkeley. The materials are prepared for national distribution by a collaboration between Addison-Wesley Publishing Company, Lab-Aids Inc., and CEPUP. The final package is in the form of modular kits containing equipment and supplies produced by Lab-Aids and printed matter published by Addison-Wesley. The modular kits are available from Lab-Aids, Addison-Wesley, Fisher Scientific Company, Sargent-Welch Scientific Company, and Science Kit and Boreal Laboratories. Refer to the last page of this document for ordering information.

### Introduction to CEPUP

CEPUP is a diverse educational program highlighting chemicals and their uses in the context of societal issues, so that learners experience the reality of science. Students collect and process scientific evidence and use it to make decisions. As a result, they begin to appreciate both the power and limitations of science. The goals of CEPUP are:

- To provide educational experiences focusing on chemicals and their interaction with people and the environment
- To promote the use of scientific principles, processes, and evidence in public decision making
- To contribute to improving the quality of science education in America
- To enhance the role of science teachers as educational leaders

CEPUP does not teach students what decisions to make. Instead, it provides the necessary knowledge and understanding so that they can more effectively make their own decisions as participating members of a free and democratic society.

### CEPUP and the Learner

During the middle/junior high school years students are becoming more independent in many ways, and the middle/junior high school expects greater independence and maturity on the part of its students. Longer-term, complex academic assignments become the norm. Essentially, there is a transition from the home-dependent years of childhood to the self-oriented independent years of adulthood. Effective independent adulthood in our society requires that the individual be able to process, evaluate, and use evidence and ideas in order to make informed decisions in the best interest of oneself and society. Experience-based science such as CEPUP is an excellent way to help middle/junior high school youth develop the evidence-based decision-making skills and capabilities necessary to become effective, contributing members of society. The emphasis on concrete experiences mixed with inference and decision making helps foster the transition from concrete to abstract thinking that is so important to the intellectual development of learners at this age level.

### The Development Process

The CEPUP approach to materials design and development is based on the premise that effective instructional development takes place with the direct and continuous participation of classroom teachers.

Module ideas are identified by program staff, associated university and industry scientists, teachers, and Advisory Board members. The program staff tries out ideas and comes up with a pilot module. A pilot kit is assembled, and draft module evaluation materials are developed. The pilot module is tested by two to four teachers of 7th to 9th grade science classes from San Francisco Bay Area Schools.

Module field tests involve up to one hundred teachers distributed among ten to fifteen sites in different states. Field testing is partially supported by the grant from the National Science Foundation, and materials are provided by Lab-Aids Inc., the CEPUP equipment supplier. The field tests are coordinated by the CEPUP National Field Test Center Directors, educational leaders associated with universities, school districts, and state departments of education. Members of the National Science Teachers Association Middle Level Division teacher network are also provided the opportunity to field test materials.

Staff and Director observations, scientific review panel comments, teacher feedback, students' success on cognitive and attitudinal assessment materials, verbal comments from teachers and administrators, completed student sheets, and analysis of used equipment packages all provide feedback on the success of a module during field testing and allow for the incorporation of regional interests and concerns. This feedback is used to revise and produce the final version of the module and kit for widespread commercial distribution.

### The Manual

The CEPUP manual contains all the information necessary for teaching the module.

**Activity Overview** The Activity Overview describes the module and its activities, giving you a general feel for what students will do during their work with the module. A module contains from five to seven activities.

**Conceptual Overview** The Conceptual Overview displays the major concepts in the module. These are chosen after considering the current expectations for science education in major states and school systems in the United States. Science concepts and processes can be cross-referenced to your textbook or course curriculum. Related societal issues are a major focus of all CEPUP materials.

**The Activity** The activity has a standard format in all modules. On the first page there are an overview, time recommendation, purpose statements, materials list, and advance preparation suggestions. These are followed by an introduction and step-by-step suggestions for discussion and carrying out the activity. Where student questions are suggested, possible responses are provided to give you some feeling for how the activity will unfold in your classroom. At the end of the activity there are the student sheet black line masters that are to be duplicated for classroom use.

**Achievement Test Item Bank** A test item bank for teacher use will be found at the end of each manual. Many of the items are objective; short answer and essay type questions are also provided. Answers are provided.

**Glossary** Background material is located at the end of the manual in the form of a glossary. Other background material will be included within the activity.

## INTRODUCTION

**Preparation of solutions** A CEPUP kit contains solutions and materials for five classes of 32 students each. Directions are given at the back of the module for preparing additional amounts of the solutions and obtaining the other materials. Most of the reagents are not costly, and supermarket sources are listed when appropriate. The tip of the bottles comes off for refilling. Refill kits are available from all CEPUP distributors.

**Kit contents** A listing of the contents of the kit is provided. All kits include relevant Material Safety Data Sheets (MSDS).

### The Kit

Teachers in schools without formal laboratories have been quite successful using CEPUP materials. A source of running water is convenient but not necessary. Two or more containers of water and buckets to collect waste serve nicely.

**The CEPUP Tray** The CEPUP Tray is an integral part of the program and is used in most modules. It can be thought of as nine small test tubes and five small beakers in one package. It rinses quickly, dries easily, and stacks for storage. The trays are exceptionally durable, but should not be used with an open flame or organic solvents. Many teachers are using CEPUP trays for other science activities instead of glassware, which may be easily broken.

**Set up and storage** CEPUP materials are exceptionally easy to set up and store. When setting up for an activity, many teachers have students prepare trays of materials for the class. Alternately, fully equipped trays may be presented for student pick-up, or a monitor may be assigned to get materials for each group.

**The 4-2-1 Model** The 4-2-1 model is our concept of a CEPUP lab group. Materials including dropping bottles, solid reagents, and specialty items are shared by a group of four students. Pairs of students share a CEPUP Tray. Each student has a copy of the student sheet. The model provides opportunities for cooperative learning throughout the module.

**Safety** The great majority of CEPUP solutions and materials pose no serious health hazards if accidentally spilled on the skin. Ingestion and contact with eyes is another matter. We recommend that safety eyewear be worn by students whenever they are working with chemicals in a laboratory situation. Your school policies and procedures for safety should, of course, be followed at all times.

### Assessment

The CEPUP team is working on an extensive program to develop more effective ways to assess the effects of CEPUP on students' general understanding of and attitudes about science and technology. If you are interested in participating in this effort or in using some of the instruments developed, please contact us.

### CEPUP and the Teacher

The purpose of the CEPUP manual and kit is to provide a resource for you, the teacher. These instructional materials are intended to help you enhance and improve your overall interaction with the learners in your classes. Without your input, our efforts are incomplete and trivial. The classroom is CEPUP's laboratory and we look forward to hearing from you about the experience you have with the materials. Through your interest and input, we will be able to improve the quality and applicability of current and future CEPUP materials. Contact us at CEPUP, Lawrence Hall of Science, University of California, Berkeley, CA 94720; telephone: (415) 642-8718, FAX (415) 642-1055.

## Chemical Survey & Solutions and Pollution

### *Chemical Survey*

#### **Activity One**

Students take a survey and tally the results. They consider the inconsistencies in their answers and learn some basic facts about chemicals, including that every thing that has mass is made of chemicals.

#### **Activity Two**

The data from the class survey is further analyzed with the emphasis on the difference between knowledge and feeling. The influences on students' ideas about chemicals are explored.

#### **Activity Three**

Students bring in surveys completed by adults and tally the results. They compare class results with adult responses and write a report.

### *Solutions and Pollution*

#### **Activity One**

Students are introduced to water as an essential and finite resource. They explore the water solubility of various substances, learning about solutions, solvents, solutes, dilute and concentrated.

#### **Activity Two**

Students learn about parts per million through a visual demonstration using the successive dilution of food coloring.

#### **Activity Three**

Using the concepts of successive dilution, concentration, and solutions, students explore the reactions of an acid, a base, water, and universal indicator when mixed together in various quantities.

#### **Activity Four**

Students evolve an operational definition for acid and explore the color range of universal indicator. They find that acids and bases become more like water when successively diluted. They explore the question of whether dilution is the answer to water pollution.

#### **Activity Five**

Students are introduced to the concept of acid-base neutralization and carry out an experiment to determine the relative concentrations of two solutions. Molecular concentration may be introduced.

#### **Activity Six**

Students design and carry out an experiment to determine the concentration of household ammonia relative to a known base solution. They may determine the relative concentration of vinegar, and discuss the idea that the supermarket is a chemical supply house.

#### **Activity Seven**

Students use their acquired knowledge to solve a simulated water pollution problem. They then discuss whether this is a true answer to pollution. The concept of the acid-base reaction and the products that are formed may be introduced.

## Chemical Survey & Solutions and Pollution

| Science concepts                                                               | Processes                                                                                     | Societal issues                                                   |
|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| Define <i>chemical</i> .                                                       | Experience survey research techniques.                                                        | Realize that everything that has mass is made up of chemicals.    |
| Define <i>natural</i> and <i>manufactured</i> .                                | Analyze data.                                                                                 | Explore influences on ideas about chemicals.                      |
| Explore basic chemical facts.                                                  | Compare data                                                                                  | Report on analysis of survey.                                     |
| Define <i>mixture</i> , <i>solution</i> , <i>solute</i> , and <i>solvent</i>   | Define <i>observation</i> , <i>description</i> , and <i>inference</i> .                       | Learn about the uniqueness and importance of water.               |
| Define <i>dilute</i> , <i>concentration</i> , and <i>successive dilution</i> . | Introduce <i>ratio comparison</i> , <i>percent concentration</i> , and <i>powers of ten</i> . | Experience parts per million (ppm)                                |
| Experience <i>acid-base indicators</i> .                                       | Conduct systematic experimentation.                                                           | Investigate an unknown.                                           |
| Define <i>acids</i> and <i>bases</i> .                                         | Use observation and inference to develop an operational definition.                           | Is dilution the answer to pollution?                              |
| Conduct <i>acid-base neutralization</i> .                                      | Make inferences about particles, molecules, and ions.                                         | Use bar charts to analyze and understand trends in data.          |
| Conduct an <i>acid-base titration</i> .                                        | Design an experiment.                                                                         | Consider the supermarket as a chemical supply house.              |
| Apply neutralization to solve a simulated practical problem.                   | Learn about ratios and proportions.                                                           | Understand the relationship between neutralization and pollution. |

## Risk Comparison

### Activity One

Students are introduced to chance and probability as they flip coins and roll dice. They analyze their results and compare class data to group data. The idea that the number of tests will make a difference to the correlation of the results with the mathematical theory is introduced.

### Activity Two

Students read and react to a story requiring a personal decision –whether to be inoculated against an unknown disease or not. The decision is used to illustrate the idea that there are many factors involved in risk and the decision as to whether a risk is worth taking is different for every individual. The concept of the risk of dying as a part of life is introduced. Students are asked to bring in pictures of risk.

### Activity Three

Students present, categorize, and discuss pictures that show all of life involves risk. Risk comparison is introduced using a list of 20 risks associated with life. Students rank activities according to which they think are the most risky and which they think are the least. Then they categorize the risks: those they have to accept (involuntary); those they choose to accept (voluntary); and those they reject (avoidance). The concept of risk-benefit analysis is introduced.

### Activity Four

Students read and react to the story of smallpox inoculation and immunization. Through discussion these events provide an example of need to make decisions involving risk. A debate highlights the concept that when it comes to risk taking, not making a decision can have consequences.

### Activity Five

The story of John Snow's research on cholera is used to further introduce epidemiology and the importance of keeping careful records when analyzing risks.

### Activity Six

The concept of risk comparison using the CEPUP approach is introduced. Students re-evaluate their ranking of the 20 risks associated with life from Activity Three. This leads to a discussion of the importance of being risk conscious when making decisions.

## Risk Comparison

### Science Concepts

Define probability and chance.

Define epidemiology.

Define risks involved in everyday life.

Explore epidemiology and risk analysis using historical data.

Experience the difference between voluntary and involuntary risk.  
Explore risk-benefit analysis.

Explore the use of epidemiology in the assessment of risk.

Experience a quantitative approach to risk analysis and risk comparison.

### Processes

Compare probability as a mathematical model and as experimental results

Analyze the different factors that are involved in an individual's determination of risk.

Observe how different individuals rank the same risks. Compare perceptions of risk with facts.

Observe the use of epidemiology in risk analysis.

Consider risk-benefit analysis as a method of evaluating the impact of a risk.

Analyze risk assessment.

Explore risk analysis and comparison in individuals' lives.

### Societal Issues

Can the mathematical model of probability and chance be translated to real life?

How do individuals determine whether a risk is worth taking?

Is life risky? How do individuals' perceptions of a risk vary?

Can historical data be used in scientific studies?

What is risk-benefit analysis? How does it relate to risk and the individual?

Can one individual decide for another whether a risk is worth taking?

How can an individual reduce risk in his or her life?

## Determining Threshold Limits

### Activity One

The threshold of taste for salt in a solution is determined for volunteers. The class analyzes the data using a bar chart and considers the limitations of taste as a test for determining the presence of salt in a solution.

### Activity Two

Students are introduced to the concept of a reagent. Using two reagents and four known solutions, they play detective to discover the identity of single and combination unknown solutions. Performing this activity introduces chemical properties and qualitative analysis in a manner that encourages students to use deductive reasoning.

### Activity Three

Emphasis is placed on the need to know how much is present, not just that it is there. Students use the reaction of salt solution and potassium chromate with silver nitrate from (Activity Two) to do a quantitative analysis of different concentrations of salt solution. They produce a standard curve from their data and are introduced to interpolation and extrapolation.

### Activity Four

The students use the reaction explored in the quantitative analysis of salt to simulate an animal experiment. They explore the effect of a potentially toxic substance (silver nitrate) on rats (salt solution and potassium chromate). By varying more than one factor the importance of a controlled experiment becomes apparent.

### Activity Five

Incorporating the idea of a controlled experiment developed in Activity Four, students further explore the effect of the potentially toxic substance. They learn the importance of recording and analyzing data, and then drawing conclusions. Students are exposed to the realities of using animal experiments to determine toxic levels for humans.

### Activity Six

Activities Four and Five are simulations of acute toxicity tests. Using given experimental data students in this activity explore the difference between acute and chronic toxicity. They learn the meaning of the term  $LD_{50}$  and consider how safe is safe when talking about a carcinogenic substance.

## Determining Threshold Limits

### Science Concepts

Define threshold limit values. Identify taste as a chemical process. Review parts per million.

Conduct qualitative analysis. Learn about chemical formulas and equations (optional).

Conduct quantitative analysis.

Relate toxicity levels to amount and length of exposure. Learn the meaning of  $LD_{50}$ . Learn to express dose in mg/kg.

### Processes

Observe threshold of taste for salt solution. Analyze data using a bar chart.

Observe characteristic properties of selected chemicals. Use characteristic properties in the identification of an unknown. Learn to use deductive reasoning in the identification of an unknown.

Use a standard curve in the analysis of an unknown. Extrapolate and interpolate from experimentally determined, graphed data.

Use simulated animal experiments to study acute and chronic effects of a potentially toxic substance. Analyze data and draw conclusions using typical data from actual animal experiments.

### Societal Issues

Is our drinking water pure? Can the quality of our drinking water be determined by taste and smell?

What are the policy implications of the presence of potentially harmful chemicals in our drinking water?

How do we measure the amount of a potentially harmful substance present in various water samples? What is the proper method of a disposing of a harmful substance?

How are toxicity levels for potentially toxic substances determined? What are the factors we need to consider in extrapolating data from animal experiments into useful information for humans?

## Investigating Groundwater: The Fruitvale Story

### Activity One

The concepts of *aquifer* and *aquitard* are introduced as students measure the length of time it takes water to move through various earth materials. These experiences are then discussed in terms of their relation to the movement of water under the surface of the Earth.

### Activity Two

Students perform a serial dilution of food coloring and water that introduces the concept of *parts per million (ppm)* and *parts per billion (ppb)*. They notice that the intensity of the color decreases as the solution is diluted, until at a concentration of one part per million, the color is usually no longer visible.

### Activity Three

Students read and discuss the story of the groundwater problem in Fruitvale. Applying what they have learned about groundwater movement, they use a map of Fruitvale to determine where additional test wells should be drilled to discover the source and measure the extent of the contamination.

### Activity Four

The students use their individual well testing plans from the previous activity to determine group well testing plans. They carry out a simulation of the well testing, modifying their original plans according to the results they obtain. The results are recorded on a map of Fruitvale.

### Activity Five

Using the map and results from activity four students draw a plume showing the boundary of safe concentration levels of the pesticide. The notions of uncertainty in sampling, testing, and interpretation of results are illustrated through the comparison of results and plumes.

### Activity Six

This is an optional activity to introduce role-play. Students select a method of decision-making, choose a topic of common interest, pick roles, and present those points of view to the class. The class decides upon an answer using the method selected.

### Activity Seven

Students role-play different members of Fruitvale at a town meeting. Eight presenters discuss clean-up plans. Students consider the duality of their roles, as both citizens and advocates. The class chooses one of the methods presented using the method decided in Activity Six.

## Investigating Groundwater: The Fruitvale Story

### Science Concepts

Factors affecting movement of groundwater: porosity, permeability.  
Aquifer and aquitard.

Dilution, concentration, and serial dilution. Parts per million (ppm).

Behavior of chemicals in solution. Toxicity of chemicals.

Pollutant concentration.

Chemical nature of pesticide contamination. Factors affecting establishing safe limits.

Methods of treating contaminated soil and groundwater: containment, excavation, incineration.

### Processes

Investigate factors affecting groundwater movement; make predictions and describe experimental results.

Use ratio comparison and percent concentration. Observe and infer.

Identify key information to develop and use hypotheses.

Perform simulated testing of pollutant levels in well samples. Revise hypotheses.

Use interpolation and plotting skills. Compare results with other students. Explain unforeseen outcomes.

Present various clean up options and consider the advantages and disadvantages of each. Analyze decision-making processes.

### Societal Issues

How does groundwater get contaminated, and how is contamination spread? Uncertainty and limits of data-gathering.

How can we make informed decisions based on evidence we cannot directly experience?

Decision-making based on evidence and the use of reasonable inferences.

What are the limits of scientific knowledge? What are the limits on research imposed by technical and economic resources?

Uncertainty as a factor in making decisions. Limits in accuracy of data collection and analysis influence decision-making.

Solutions to problems generate more problems. Science can provide the evidence for a decision, but decisions depend on judgement of individuals. The same evidence may be used to arrive at very different conclusions.

## Toxic Waste: A Teaching Simulation

### Activity One

Students explore the behavior of ions in solution in order to understand the electroplating process. The conductivities of water, salt, sugar, and copper chloride solutions are compared. Copper chloride solution is then used to electroplate an object and students are presented the problem of disposing of the toxic used copper chloride solution.

### Activity Two

Students use a 50,000 ppm used copper chloride solution to represent any solution containing a toxic heavy metal that cannot be reclaimed. In a hypothetical local sewer district, regulations will permit disposal if the maximum concentration of the toxic heavy metal does not exceed 5 ppm. Students use successive dilutions to determine the volume of water needed to dilute to that concentration. The use of household ammonia as a chemical test for copper in solution is introduced. Students may also explore the lower limit of sensitivity for the ammonia test. Dilution as a treatment procedure is evaluated.

### Activity Three

Many industrial chemical processes produce materials that contain valuable substances that can be economically reclaimed, recycled, or sold as a by-product. In this activity, students investigate use of aluminum to reclaim valuable copper metal from the used copper chloride solution generated by electroplating.

### Activity Four

Do other metals remove copper from the used copper chloride solution as did aluminum? Students compare aluminum, iron and zinc, examining cost and safety information to decide which metal would be the best to use. The weighing of various factors in making a use decision is highlighted.

### Activity Five

Different solutions are added to the used copper chloride solution to produce a precipitate. The precipitate is filtered and the filtrate solution is tested with ammonia to determine which precipitation reaction is most effective in removing copper ions. To simulate conditions at a sanitary landfill site subject to exposure from acid rain or runoff, students add dilute acid (vinegar) to each precipitate and then test the filtrate with ammonia. They then consider the effectiveness of precipitation for removing and securing the toxic metal ions under simulated environmental stresses.

### Activity Six

Students investigate a process that converts the toxic copper waste to a solid using Portland cement and sodium silicate. The ability of the resulting products to resist leaching of the copper ions by dilute acid is tested.

### Activity Seven

Students review the various processes for handling the toxic waste, comparing the advantages and disadvantages of each method in relation to the ultimate fate of the material, ease of carrying out the process, cost, and general environmental concerns. The importance of source reduction in all waste management decisions is emphasized.

## Toxic Waste: A Teaching Simulation

### Chemistry Concepts

Toxic waste, ions, electrolytes and non-electrolytes, conductivity, electron flow, and electroplating; heavy metals.

Successive dilution and parts per million.

Aluminum replacement reaction, waste treatment, waste reduction.

Other metal replacement reactions.

Precipitation reactions, filtrate, leachate, acid rain.

Solidification and stabilization; leaching into groundwater.

Review dilution, replacement, precipitation, and solidification. Local disposal techniques for liquid wastes.

### Processes

Observe evidence of conductivity in solutions; investigate electroplating of copper.

Perform a successive dilution; calculate the amount of water needed for dilution; explore use of ammonia as a test for copper ions.

Perform a metal replacement reaction; observe and interpret evidence of chemical reaction.

Investigate the ability of various metals to replace copper ions in solution.

Perform precipitation reactions and filter precipitates; determine the stability of the copper precipitates in weak acid solutions.

Prepare samples of different solidified and stabilized copper solution; test and evaluate samples.

Identify advantages and disadvantages of the different chemical processes. Properly dispose of liquid wastes.

### Societal Issues

Chemical reactions used in industry produce toxic wastes that pose disposal problems. What can be done?

Is using water to dilute solutions containing toxic heavy metal waste to legal levels for disposal an answer?

Toxic wastes often contain useful materials that can be reclaimed, reducing the amount of waste generated.

Different metals can be used to reclaim substances from waste solutions. Decisions must consider effectiveness, cost, and regulations. What problems does reclaiming solve and create?

Precipitation is used to treat toxic wastes. Environmental factors must be considered in selecting methods of treatment and disposal.

Solidification and stabilization of toxic wastes can result in legal landfill disposal; cost effectiveness of the process must be considered.

Recommendations must be based on evidence. Source reduction is a goal in all toxic waste situations.

## Plastics In Our Lives

### Chemistry concepts

Polymers are a part of many common materials. Oil, gas, and coal are the basic plastic feedstocks.

Solubility, melting point, and density are useful in identifying plastics.

Polymers may be synthetic or natural. Synthesis and arrangement of monomer molecules determine the polymer's properties.

Polymer molecules are synthesized from monomers. Linear and cross-linked chains affect viscosity.

Insulators work as a function of constituent molecules and space.

Degradability may be biochemical and physical. Chemical properties of plastics determine recyclability. Degradability can be engineered into plastics.

Plastic feedstock availability depends on fossil fuels.

Products contain stored energy. Explore relationships of mass and volume.

### Processes

Identify polymers in everyday substances.

Observe and categorize various physical properties of plastics. Identify an unknown polymer.

Contrast the properties of natural polymers with synthetic polymers.

Construct and interpret models to predict physical properties.

Contrast the properties of synthetic and natural insulators. Observe products made from insulators.

Examine issues involved in recycling plastics.

Examine the role and extent of plastics in various businesses in the community.

Re-examine the ideal product and summarize a variety of factors.

### Societal issues

Decision-making maybe based on ideal versus practical criteria.

Properties of substances create advantages and disadvantages in their use.

Nonrenewable resources are the major source of synthetic polymers.

Modeling processes have useful applications for the design of materials.

Natural and synthetic polymers have advantages and disadvantages in their use and applications.

Recycling of plastic materials is one solution to disposal problems.

The use of plastic materials involves trade-offs in the decision-making process.

Energy costs are a hidden but important consideration in product design.

## Plastics In Our Lives

### Activity One

Plastic or paper bags? Students classify their responses to this question and develop criteria for an ideal bag, and the reasons for selecting one over the other. They become aware of common plastic products, define *plastic* and *polymer*, and list sources of plastics. The activity concludes with an investigation of the "stretch" of a plastic trash bag in different directions.

### Activity Two

Physical properties of four common plastics are examined and the advantages and disadvantages of plastics and natural materials are compared. Students use physical properties to identify unknown plastic samples and are introduced to names and uses of common plastics and fibers.

### Activity Three

Students learn that polymers can be either synthetic or natural and that polymerization produces molecules containing thousands of monomer units. They then synthesize two cross-linked polymers: Slime® (a polyvinyl alcohol cross-linked polymer) and a natural cross-linked polymer made from gelatin and compare the physical properties of the reactants and products. Films of the polymers are made and compared with the plastic trash bag film from Activity One.

### Activity Four

Students use paper clips to make models of a polymer molecule and then relate physical behavior to molecular structure. They associate properties of polymers with types of bonding and discuss the value of the model in helping to understand the polymerization process and some of the physical properties of polymers.

### Activity Five

Students compare properties of natural and synthetic polymers - the insulating value of popcorn versus polystyrene foam and the absorbancy and strength of disposable versus cotton diapers. They discuss advantages and disadvantages of synthetic and natural polymers.

### Activity Six

Using disposable diapers from the previous activity as an example of solid waste, students examine issues relating to the disposal of plastics. They view a videotape on recycling plastics and discuss recycling as a way to reduce plastic waste. They experiment with a thermoplastic material as a model for plastic recycling and discuss alternatives to the disposal of plastics.

### Activity Seven

Students examine how reduced availability and increased cost of plastic feedstocks in a hypothetical oil supply crisis might affect typical businesses. They explore alternatives to the use of plastic products and discuss the advantages and disadvantages of giving priorities to certain types of businesses. Students prepare and present a report of their findings.

### Activity Eight

Students reconsider their decisions regarding the use of plastic or paper bags. They examine the energy needs for producing various plastic products compared to similar paper or metal items. Reviewing major module concepts, they explore energy use, waste disposal, and biodegradability and complete a "decision matrix" before re-voting on the bag issue. They learn that decisions often involve trade-offs or compromises that are not ideal solutions to problems.

## Investigating Chemical Processes: Your Island Factory

### Chemistry Concepts

Various industries use chemical reactions to make products. These reactions vary according to industry type.

Chemical reactions produce products and by-products. By-products that have no use must be recycled or disposed of. Vinegar and salt may be used to clean pennies.

Chemical reactions are used for specific tasks. Industries must provide necessary conditions for reactions to occur. By-products must be dealt with.

An "island economy" has limited resources. Products can be made from available raw materials. Surface area affects reaction rate.

Two-step synthesis of gypsum (calcium sulfate) from calcium carbonate, hydrochloric acid, and sodium sulfate. Precipitation and filtration.

Scaling up a reaction from the laboratory to industry. A factory needs raw materials, labor, storage, waste disposal, and energy.

### Processes

Rate industries using an attitude scale. Discuss perceptions of industry impact on a community. Develop a list of local concerns.

Investigate a chemical reaction and classify reactants, products and by-products. Observe and infer.

Develop understanding of specific industries. Compare preferences with earlier perceptions.

Develop an operational definition for carbon dioxide. Investigate surface area vs. reaction rate. Differentiate products from by-products. Appreciate the need for useful products.

Separate a precipitate. Compare properties of reactants and products. Differentiate products from by-products. Suggest uses for by-products or ways to dispose of them.

Design a plan for a factory. Consider difficulties in scaling up. Analyze ways of meeting factory needs. Investigate methods of waste disposal and recycling. Evaluate groups' factory plans.

### Societal Issues

What factors must be taken into account to evaluate the impact of an industry on a community? Can people agree on common criteria to evaluate desirability?

Classifying industry as "good" or "bad" is based on evaluation of its products and by-products. Is this productive? What other issues does it raise?

How does a community weigh advantages and disadvantages in order to make a decision about siting a factory? Do all factors have equal weight?

Society values consumer products while trying to avoid raw material and disposal problems. NIMBY is not helpful; are our communities "islands?"

Products can be synthesized by different processes, each with different by-products. How do we choose from among the available methods?

Our earth is an "island." What standards should be used to effectively manage its resources? Consider wise use of raw materials, the need for products, economic and environmental concerns, and disposal of wastes.

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### Activity One

Students complete a word association survey on four representative industries that use chemicals (chemical manufacturing, computer production, food processing, and oil refining). They tabulate and analyze their responses and use them to discuss the impact of an industry on a community. They prepare a list of their personal concerns if one of these industries were built in their community.

### Activity Two

Chemical reactions are introduced as an important component of all chemical and many other industries. Students explore the meaning of *reactant*, *product*, and *by-product* in a simple reaction in which vinegar and salt are used to clean copper pennies. The definition of *waste* as a by-product which has no use is introduced.

### Activity Three

Students read brief descriptions of the chemical processes involved in the four representative industries. Common themes from these readings reinforce the following concepts: (1) industries use chemical reactions to accomplish specific tasks; (2) industries must provide the necessary conditions for chemical reactants to combine to form products; and (3) industries must either find uses for by-products or dispose of them as wastes. Students consider reasons for preferring one particular type of industry over another, if any, and compare them to their reactions to the four industries after the first activity.

### Activity Four

Students imagine that they live on an island and must use its limited resources of limestone and marble to provide jobs and useful products. Island residents are considering the possibility of producing gypsum (calcium sulfate), which has value as a building material. The procedure is a two-step synthesis using marble (calcium carbonate) and sodium sulfate. Students perform the first step while reviewing concepts from the penny activity and investigating the effect of surface area on reaction rate.

### Activity Five

Students combine calcium carbonate powder and hydrochloric acid, filter the solution of calcium carbonate produced, and then mix this solution with a solution of sodium sulfate. A fine precipitate of calcium sulfate (gypsum) forms, which is then collected by filtration and dried. By-products from each step of the reaction are considered for other possible uses or for disposal as wastes.

### Activity Six

Students groups design a plan for their factories, considering the difficulties in adapting a laboratory reaction to large scale production. They complete an environmental impact report for their factories, including the factors of availability of raw materials, energy, water management, disposal of wastes, and labor. Their reports are presented to the class, which evaluates them using the list of local concerns developed in the first activity.

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